National Park Service
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Natural Resource Stewardship and Science

# Southeast Alaska Network Freshwater Water Quality Monitoring Program

*2017 Annual Report*

Natural Resource Data Series NPS/SEAN/NRDS—2018/1144

**ON THE COVER**
Taiya River water quality monitoring location, looking downstream
NPS photo

# Southeast Alaska Network Freshwater Water Quality Monitoring Program

*2017 Annual Report*

Natural Resource Data Series NPS/SEAN/NRDS—2018/1144

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.



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# Executive Summary

Freshwater water quality is an indicator of aquatic and terrestrial ecosystem health and one of the priority Vital Signs in the National Park Service's Southeast Alaska Network (SEAN), which includes Glacier Bay National Park and Preserve, Klondike Gold Rush National Historical Park, and Sitka National Historical Park. Data collected under this program inform several management-relevant topics:

- Monitoring the frequency and magnitude of low dissolved oxygen events (hypoxia) in the Indian River in Sitka
- Measuring the natural quality of wilderness lands in Glacier Bay
- Describing effects of a changing climate on the physical and chemical properties of park waters
- Assessing whether state and federal water quality standards are met

This eighth annual report is intended to be a concise data summary and regular product for park staff, managers, superintendents, and other interested parties. All annual reports and data products are publicly available at the SEAN website (http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx), but website structure of NPS Inventory and Monitoring Programs will be changing over the next year and data products will be shifting to the NPS Data Store (https://irma.nps.gov/DataStore/Reference/Profile/2182282).

In 2017, hourly water temperature, specific conductance, dissolved oxygen, and pH data were collected in the Salmon River (Glacier Bay) from April 28 through November 1, and in the Indian River (Sitka) from April 21 through November 14. The same parameters plus turbidity were collected in the Taiya River (Klondike Gold Rush) from April 12 through November 9. No observations signaled a change to the fundamental water quality patterns of the three rivers.

Daily mean temperature for the Salmon River ranged from 4.0 to 11.0°C (peaking on August 14), while the Indian River ranged from 4.5 to 10.2°C (peaking on August 14, as well). Daily mean temperature for the glacially influenced Taiya River ranged from -0.1 to 6.9°C and peaked on August 18. Taiya River hourly turbidity measurements ranged from 1.0 to 1,045 NTU and were synchronized with high flow events.

Patterns in the medians and distributions of specific conductance, dissolved oxygen, and pH were generally similar to previously observed ranges for all three rivers. The critically low dissolved oxygen levels in the Indian River observed during summer 2013 have not been observed in subsequent years.

# Acknowledgments

This work could not be accomplished without the annual support of SEAN Program Manager M. Bower and the efforts of many park staff. B. Carter, J. Hamblen, R. Henderson, J. Hinrichs, C. Murdoch, O. Schneider, C. Soiseth, and C. Thole conducted field work and transmitted data for processing. The SEAN Vital Signs program is supported by funding from the NPS National Inventory and Monitoring Program and the NPS Water Resources Division.

# List of Acronyms and Abbreviations

| | |
|---|---|
| °C | Degrees Celsius |
| cfs | Cubic feet per second |
| DO | Dissolved oxygen |
| GLBA | Glacier Bay National Park and Preserve |
| KLGO | Klondike Gold Rush National Historical Park |
| $m^3/s$ | Cubic meters per second |
| mg/L | Milligrams per liter |
| mS/cm | Millisiemens per centimeter |
| NPS | National Park Service |
| NTU | Nephelometric Turbidity Units |
| SEAN | Southeast Alaska Inventory & Monitoring Network |
| SITK | Sitka National Historical Park |
| SOP | Standard Operating Procedure |
| USGS | United States Geological Survey |

# Introduction

Water quality is an indicator of aquatic and terrestrial ecosystem health in Southeast Alaska, a rainforest landscape dominated by a wet and mild maritime climate. The Southeast Alaska Network (SEAN) of the National Park Service (NPS) has prioritized Freshwater Water Quality as one of its Vital Signs for long-term ecological monitoring based on its vulnerability to alteration by human stressors and sensitivity for detecting fundamental environmental changes (Moynahan et al. 2008). Trends in water quality can signify chronic or developing watershed issues within national parks.

The SEAN water quality monitoring program has the following objectives:

- Track the status and trends of each core water quality parameter (specific conductance, dissolved oxygen, pH, and water temperature; plus turbidity in the Taiya River) for at least one river in each SEAN park unit
- Describe the timing and magnitude of seasonal and annual variation for each core water quality parameter
- Evaluate whether state and/or federal water quality standards are met or exceeded

The SEAN water quality monitoring protocol (Sergeant et al. 2013) includes an extended description of each water quality parameter in Section 1.6. Briefly, specific conductance measures the ability of water to conduct an electrical current at a standardized temperature of 25°C. In Southeast Alaska, higher values generally represent groundwater influence and lower values represent rain and snow runoff. Dissolved oxygen (DO) is a measure of the amount of microscopic oxygen bubbles in water which is essential for aquatic organism respiration. DO is mainly regulated by temperature, but fluctuations in DO can be caused by other factors such as organic matter accumulation, biological respiration or decomposition, and water aeration. The pH of water is a unit-less measure of hydrogen ion concentration reflecting relative acidity or alkalinity; it affects aquatic organism respiration, salt exchange, and many biogeochemical processes. Turbidity is a measure of water clarity; increases in turbidity typically signal glacial runoff.

This report summarizes results from the 2017 sampling season and compares them with data collected since 2010. SEAN staff are currently drafting a synthesis report presenting more in-depth trend analyses and broadened discussion of programmatic successes and necessary modifications. Guidance for annual report formatting and analysis is described in Standard Operating Procedure (SOP) 10 of the water quality monitoring protocol (Sergeant et al. 2013).

## Study areas

The sampling goal of this monitoring program is to track water quality status and trends in at least one river in each of the three SEAN parks. In 2010, sonde locations were finalized for the Salmon (GLBA) and Indian (SITK) Rivers. The Taiya River (KLGO) was added in 2011. Sampling sites were chosen based on individual park interests and dependable long-term site access (Figure 1). Until the SEAN freshwater water quality monitoring program began, no long-term continuous data were available for any park rivers (Eckert et al. 2006a; Eckert et al. 2006b; Hood et al. 2006).

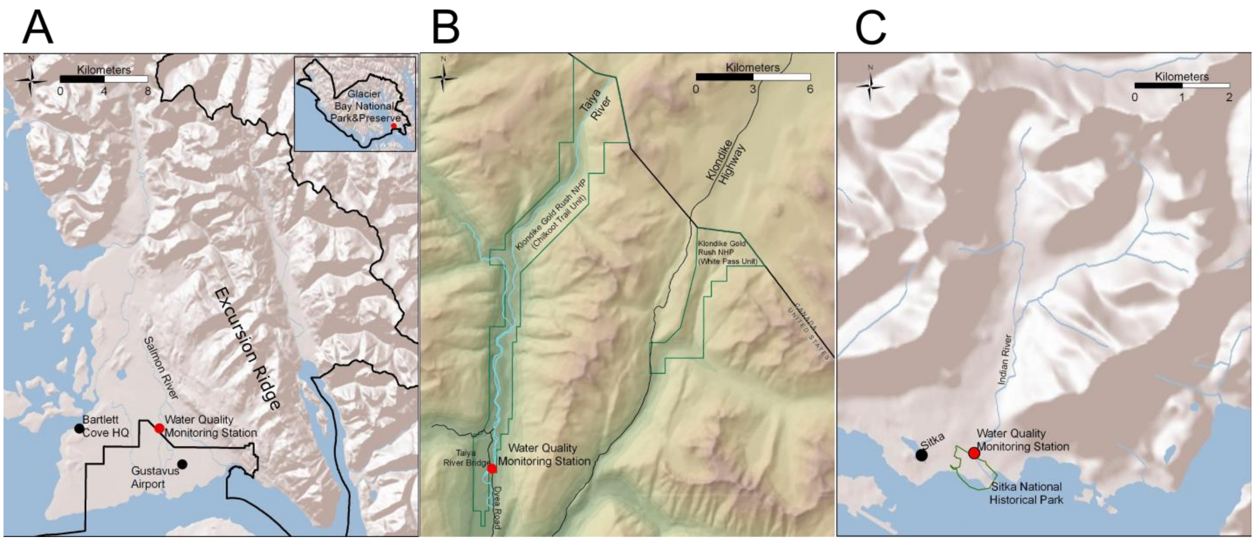


**Figure 1.** The three SEAN water quality monitoring station locations (solid red circles). (A) Salmon River in GLBA; black line denotes park boundary (B) Taiya River in KLGO; green lines denote park boundaries (note that the park units are not contiguous) (C) Indian River in SITK slightly upstream of park boundary; green line denotes park boundaries.

### *Salmon River (GLBA)*

GLBA, the largest park unit in the SEAN, has at least 310 streams (Soiseth and Milner 1995) flowing for over 3,380 km through a diverse landscape. Upstream of the water quality monitoring station, the Salmon River is 32.7 km long within a 9,600 ha watershed that collects most of its water from Excursion Ridge to the east (Figure 1A; Table 1). The water quality monitoring site is located on the river left bank (facing downstream) at approximately river km 9.0 (Figure 1A; Table 1) several meters upstream of the NPS boundary. The lowermost portion of the river (river km 0.0 to 9.0) is outside of NPS boundaries and within the town of Gustavus. The Salmon River has gravel riverbed habitat and supports populations of gamefish species such as pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), cutthroat trout (*O. clarkii*), and Dolly Varden (*Salvelinus malma*; Eckert et al. 2006a). Staghorn (*Leptocottus armatus*) and coastrange sculpin (*Cottus aleuticus*) have been observed in the river (C. Soiseth, personal communication). Since May 15, 2014, USGS has monitored stage, discharge, and water temperature for the Salmon River approximately 1 km downstream from the park boundary. No significant tributaries exist between these two sites.

### *Taiya River (KLGO)*

The Taiya River is located west of Skagway and one of two major drainages flowing through KLGO. Upstream of the water quality monitoring station, the Taiya River is approximately 25.7 km long and drains approximately 45,500 ha (Figure 1B; Table 1). The water quality monitoring site is located on the river left bank slightly downstream of the Taiya River Bridge (Figure 1B; Table 1) and adjacent to the United States Geological Survey (USGS) streamflow gaging site. From 1970 to 2017, the annual mean discharge from the Taiya River has ranged from a minimum of 24.9 $m^3/s$ (880 cfs) in 1973 to a maximum of 43.6 $m^3/s$ (1,540 cfs) in 2013. Peak flows typically occur June through September.

Skagway is notably drier than other Southeast Alaska communities, averaging 69 cm of precipitation per year, in comparison to 142 cm in Gustavus and 217 cm in Sitka (Western Regional Climate Center Data: http://www.wrcc.dri.edu/summary/Climsmak.html). The glacial influence on the Taiya watershed is unique among streams currently monitored in the SEAN. As of 2001, approximately 36% of the watershed was covered by glaciers (Sergeant and Nagorski 2014). Glacial outburst events have led to large floods and created a highly dynamic physical environment (Hood et al. 2006). The Taiya watershed supports chum, pink, and coho salmon populations, as well as Dolly Varden. Eulachon (*Thaleichthys pacificus*) run up the Taiya River in the spring (Hood et al. 2006).

### *Indian River (SITK)*

The lowest 1 km of the Indian River is the only significant freshwater habitat within SITK and can be characterized as a low gradient alluvial channel with gravel-cobble substrate that supports anadromous fish species, including coho, pink, chum, and Chinook salmon (*O. tshawytscha*), steelhead, Dolly Varden, and non-anadromous species such as resident rainbow trout (*O. mykiss*), three-spine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (Eckert et al. 2006b). Upstream of the water quality monitoring site, the Indian River is approximately 19.8 km long within a steep and well-drained 3,100 ha watershed (Figure 1C; Table 1). The monitoring site is located on the river right bank approximately 60 m upstream of park boundaries at river km 0.8 (Figure 1C; Table 1). From 1980-2006, USGS monitored stage and discharge at the same site. From June 2007 through April 2016, NPS collected stage and occasional discharge measurements after USGS streamflow program reductions (Sergeant and Schwarz 2017). But, thanks to a collaborative funding agreement including NPS and the City and Borough of Sitka, USGS once again began monitoring stage and discharge at the same site on February 9, 2016 (Table 5).

**Table 1.** The three SEAN water quality monitoring stations watershed characteristics. Watershed characteristics were measured for the areas upstream of each monitoring station (data adapted from Sergeant and Nagorski 2014).

| River | Watershed ($km^2$) | Length (km) | Max. elevation (m) | Glacier (%) | Wetland (%) | Forest (%) | Sampling site (river km) |
|---|---|---|---|---|---|---|---|
| Salmon | 96 | 32.7 | 1079 | 0 | 37 | 44 | 9 |
| Taiya | 455 | 25.7 | 1829 | 36 | 2 | 20 | 3.5 |
| Indian | 31 | 19.8 | 1158 | 1 | 18 | 55 | 0.8 |

# Methods

## Station instrumentation

The Salmon, Taiya, and Indian Rivers were sampled hourly for specific conductance (mS/cm), dissolved oxygen (concentration [mg/L] and saturation [%]), pH, and water temperature (°C). Additionally, turbidity (NTU) was measured in the Taiya River. The final data set is currently downloadable from the SEAN website (http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx), but website structure of NPS Inventory and Monitoring Programs will be changing over the next year and data products will be shifting to the NPS Data Store (https://irma.nps.gov/DataStore/Reference/Profile/2182282). Future reports will detail where data are housed. Multi-parameter water quality sondes (Table 2) collected and logged data at single fixed sites in the Salmon River from April 28 through November 1, the Taiya River from April 12 through November 9, and the Indian River from April 21 through November 14 (Figure 1; Table 3). Each year, sampling is planned to occur from at least May 1 through October 31, and extends into November if ice conditions and staff resources allow.

**Table 2.** YSI, Inc. instruments used for 2017 water quality sampling.

| Equipment description | Model number |
|---|---|
| Multi-parameter water quality logger | 6920V2-2 |
| Multi-parameter display system | 650 |
| Conductivity/temperature probe | 6560 |
| pH probe | 6561 |
| Optical oxygen sensor | 6150 |
| Optical turbidity sensor (Taiya River only) | 6136 |

**Table 3.** Summary of 2017 freshwater water quality sampling effort. F (dark gray) = full month; P (light gray) = partial month.

| | Month | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| River | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Core parameters collected? |
| Salmon | P | F | F | F | F | F | F | P | Y |
| Taiya | P | F | F | F | F | P | P | P | Y[1] |
| Indian | P | F | F | F | F | F | P | P | Y[2] |

[1] From August 12 to August 28, specific conductance sensor was calibrated incorrectly; From September 14 to October 5, sonde did not collect data

[2] From October 18 to October 30, sonde did not collect data

In all three rivers, a sonde was mounted inside a perforated 4-inch ABS pipe. In the Salmon River the pipe was attached to an angle-iron rod set in the streambed, while in the Taiya and Indian Rivers the pipe was bolted to a large boulder in the stream channel. A bolt mounted through the ABS pipe set the sonde height in the water column. After installation, Park Leads visited the sondes approximately once per month to check calibration for each sensor and clean components, as needed. These calibration checks were used to assess data quality and ensure that the water quality instruments were functioning properly.

### Data processing

This report follows guidance provided in the SEAN monitoring protocol FQ-2013.1 (Sergeant et al. 2013). The protocol narrative and SOPs 1 through 3 describe the data collection, monthly error/calibration checks, and data processing in detail (Sergeant et al. 2013). Park and SEAN staff generally conducted error/calibration checks monthly at each water quality station from May through November (See Tables 4a, b, c in Results Section).

The SEAN has established data "ratings" and "grades" to describe overall data quality. Data ratings denote unusable measurements for reasons such as the sonde being out of water during an error/calibration check or an erroneous value due to instrument malfunction. Before analysis, most data with a '2' (depending on project leader's evaluation of data) and all data with a '3' rating were removed from the dataset. Data with '0' (no question regarding accuracy) or '1' (determined useable by the professional judgement of the Project Leader despite potential mistakes in precisely following protocols) ratings were used for analysis. SOP 13 of the water quality protocol (Sergeant et al. 2013) describes each data rating in detail. Comments contained in the water quality database are available in the NPS Data Store (https://irma.nps.gov/DataStore/Reference/Profile/2182282) and contain explanations for each assigned rating other than zero.

Data grades refer to the point-in-time accuracy of each water quality sensor as ascertained from regular error/calibration checks and range from 'Poor' to 'Excellent'. The grades determined by these point checks were back-dated to the previous error/calibration check and applied to all data during that time period. Due to potential subjectivity, the SEAN does not correct (adjust) data values based on error/calibration checks (as described in Wagner et al. 2006), but sensor values from calibration checks are available by downloading field sheets from the NPS Data Store (https://irma.nps.gov/DataStore/Reference/Profile/2182282), allowing data users to perform any particular corrections they deem appropriate.

The final datasets were analyzed and summarized according to the guidelines in SOP 10 (Sergeant et al. 2013).

# Results

## Data collection

Water quality measurements were generally high quality during 2017, but several issues were encountered with continuous data collection on the Taiya and Indian Rivers. From August 12 to 28, the Taiya River specific conductance and DO sensors were incorrectly calibrated and not logging accurate measurements. From September 14 to October 5, no Taiya River water quality data were logged due to drained batteries. From October 18 to 30, no Indian River water quality data were logged due to drained batteries. Erroneous values resulting from these problems have been removed from the analyses below.

Turbidity quality grades for the Taiya River were rated ‘Poor’ for the entire monitoring season (Tables 4a, b, c). This is a common occurrence most months and an artifact of the two-point error checking method for the sensor, which uses 0 and 126 NTU standards (see SOP 2 in Sergeant et al. 2013). The Poor quality grade is mostly attributable to the 0 NTU portion of the error checking. Low NTU standards are easily contaminated by tiny particles in the sonde calibration cup (see *Program performance* section below for more discussion). Each month, the sensor generally was in very good agreement with the 126 NTU standard. The observed values were generally within reasonable sensor accuracy expectations, but turbidity values are best used for relative seasonal trends in water clarity and less appropriate as absolute individual measurements.

**Table 4a.** Summary of 2017 freshwater water quality data grades for the Salmon River. E = Excellent, G = Good, F = Fair, P = Poor. Definitions for each grade are found in SOP 2 (Sergeant et al. 2013) and are based on USGS recommendations (Wagner et al. 2006). SC = specific conductance; DO = dissolved oxygen.

| | | Date ranges | | | | | |
|---|---|---|---|---|---|---|---|
| **River** | **Parameter** | **4/28-5/31** | **5/31-6/28** | **6/28-8/1** | **8/1-8/29** | **8/29-9/28** | **9/28-11/1** |
| Salmon | SC (mS/cm) | G | E | E | E | E | E |
| | DO (mg/L) | E | E | E | E | E | G |
| | pH | E | E | E | E | E | E |
| | Temperature (°C) | G | E | E | E | E | G |

**Table 4b.** Summary of 2017 freshwater water quality data grades for the Taiya River. E = Excellent, G = Good, F = Fair, P = Poor. Definitions for each grade are found in SOP 2 (Sergeant et al. 2013) and are based on USGS recommendations (Wagner et al. 2006). Shaded areas with "–" represent periods when data grades are not available due to sensor malfunction or improper calibration procedures. SC = specific conductance; DO = dissolved oxygen.

| | | Date ranges | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **River** | **Parameter** | **4/12-4/27** | **4/27-6/4** | **6/4-6/29** | **6/29-8/12** | **8/12-8/28** | **8/28-9/14** | **10/5-10/27** | **10/27-11/9** |
| Taiya | SC (µS/cm) | E | E | E | P | – | E | E | E |
| | DO (mg/L) | E | G | G | E | – | E | G | E |
| | pH | E | E | E | E | E | E | E | E |
| | Temperature (°C) | P | F | E | E | E | G | G | G |
| | Turbidity (NTU) | P | P | P | P | P | P | P | P |

**Table 4c.** Summary of 2017 freshwater water quality data grades for the Indian River. E = Excellent, G = Good, F = Fair, P = Poor. Definitions for each grade are found in SOP 2 (Sergeant et al. 2013) and are based on USGS recommendations (Wagner et al. 2006). Shaded areas with "–" represent periods when data grades are not available due to sensor malfunction or improper calibration procedures. SC = specific conductance; DO = dissolved oxygen.

| | | Date ranges | | | | |
|---|---|---|---|---|---|---|
| **River** | **Parameter** | **4/21-6/1** | **6/1-7/3** | **7/3-8/1** | **8/1-10/30** | **10/30-11/13** |
| Indian | SC (µS/cm) | E | E | E | E | E |
| | DO (mg/L) | G | G | E | E | E |
| | pH | E | E | E | – | E |
| | Temperature (°C) | E | E | E | E | G |

## Comprehensive time series data

Hourly time series data for all water quality parameters in all three rivers are graphed in Appendix A. Daily average streamflow time series data from all three rivers compared to daily average water quality data are in Appendix B. Indian River streamflow is reported as relative stage height because a current stage-discharge relationship (rating curve) has not been finalized by the USGS, which re-instated gaging operations February 2016. From June 2007 through March 2016, the SEAN and external partners collected stage and discharge information (Sergeant and Schwarz 2017; Table 5). In the Taiya and Indian rivers, streamflow data were collected in the same location as water quality data. The Salmon River streamflow gage is approximately 1 river km downstream of the water quality monitoring site. Starting May 15, 2014, USGS began publishing stage, discharge, and water temperature data for the Salmon River.

**Table 5.** URLs for USGS gaging stations co-located with SEAN water quality monitoring stations.

| River | USGS URL |
|---|---|
| Salmon River | https://nwis.waterdata.usgs.gov/ak/nwis/uv/?site_no=15057596&agency_cd=USGS |
| Taiya River | https://nwis.waterdata.usgs.gov/ak/nwis/uv/?site_no=15056210&agency_cd=USGS |
| Indian River | https://nwis.waterdata.usgs.gov/ak/nwis/uv/?site_no=15087700&agency_cd=USGS |

## Salmon River

### *Temperature*

Except for short time periods from mid-September to mid-October, Salmon River water temperatures from 2017 closely tracked average daily mean values from 2010-2016 (Figure 2). During the period of monitoring, the daily mean water temperature in the Salmon River ranged from 4.0 to 11.0°C and peaked on August 14 (2010-2016 average peak temperature date = August 9, standard deviation = 14 days). Median daily mean water temperature during the monitoring period was 8.2°C. Monthly mean daily average temperatures ranged from 5.7 to 10.1°C (Table 6). Variation in daily mean temperatures was similar across all months but most variable in May (Table 6).

**Table 6.** Monthly mean and standard deviation, minimum daily mean, and maximum daily mean water temperature for the Salmon, Taiya, and Indian Rivers in 2017. Only months with at least 75% of total monthly hours measured were included. See the Methods section for sonde installation dates for each river.

| | Salmon | | | Taiya | | | Indian | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | Mean daily average (SD) | Min | Max | Mean daily average (SD) | Min | Max | Mean daily average (SD) | Min | Max |
| May | 5.7 (1.0) | 3.1 | 8.2 | 5.1 (1.3) | 2.1 | 8.7 | 6.0 (0.6) | 4.6 | 8.0 |
| June | 7.7 (0.8) | 6.0 | 9.3 | 5.8 (1.0) | 3.9 | 9.1 | 7.2 (0.5) | 5.9 | 8.7 |
| July | 9.4 (0.5) | 8.1 | 10.6 | 6.0 (0.7) | 4.6 | 8.9 | 8.2 (0.5) | 7.0 | 10.2 |
| August | 10.1 (0.7) | 8.5 | 12.0 | 5.9 (0.9) | 4.5 | 8.9 | 9.3 (0.8) | 7.8 | 11.2 |
| September | 8.9 (0.9) | 6.8 | 11.0 | – | – | – | 8.7 (0.8) | 7.3 | 11.0 |
| October | 6.0 (0.9) | 4.2 | 8.3 | 4.0 (0.7) | 2.1 | 5.5 | – | – | – |

### *Specific conductance, DO, and pH*

Individual specific conductance measurements in the Salmon River ranged from 0.05 to 0.37 mS/cm with a median of 0.20 mS/cm (Figure 3). DO ranged from 8.6 to 13.1 mg/L with a median of 10.8 mg/L (Figure 3). DO reached the minimum observed value on August 12. Values for pH ranged from 6.6 to 8.1 with a median of 7.8 (Figure 3).

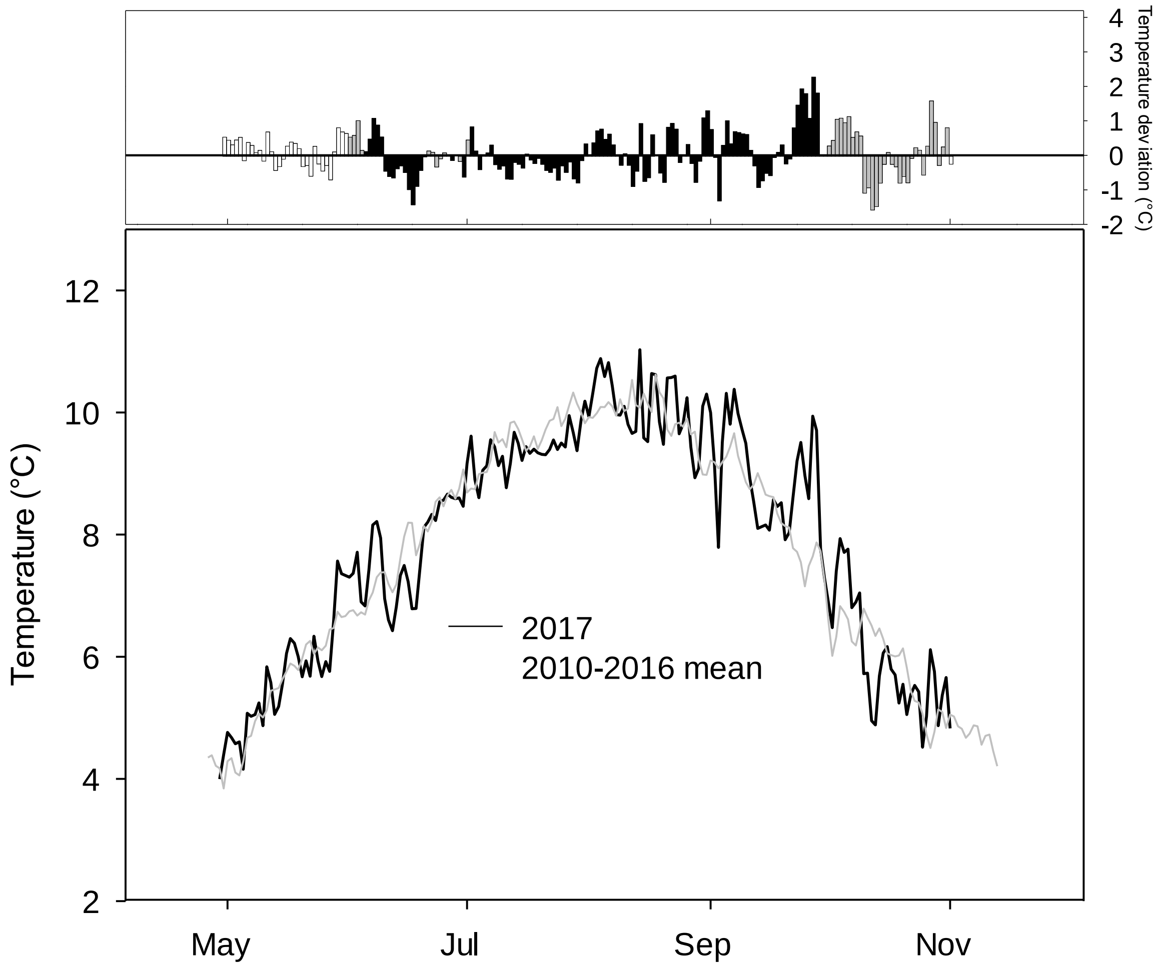


**Figure 2.** Daily mean water temperature for the Salmon River in 2017 and 2010-2016 mean (lower panel) and temperature deviations from 2010-2016 mean (upper thin panel). In the upper panel, deviations were compared against average daily temperatures calculated using 5 years of historical data (white bars), 6 years (gray bars), or 7 years (black bars). Due to the short time series, interpret deviations cautiously.

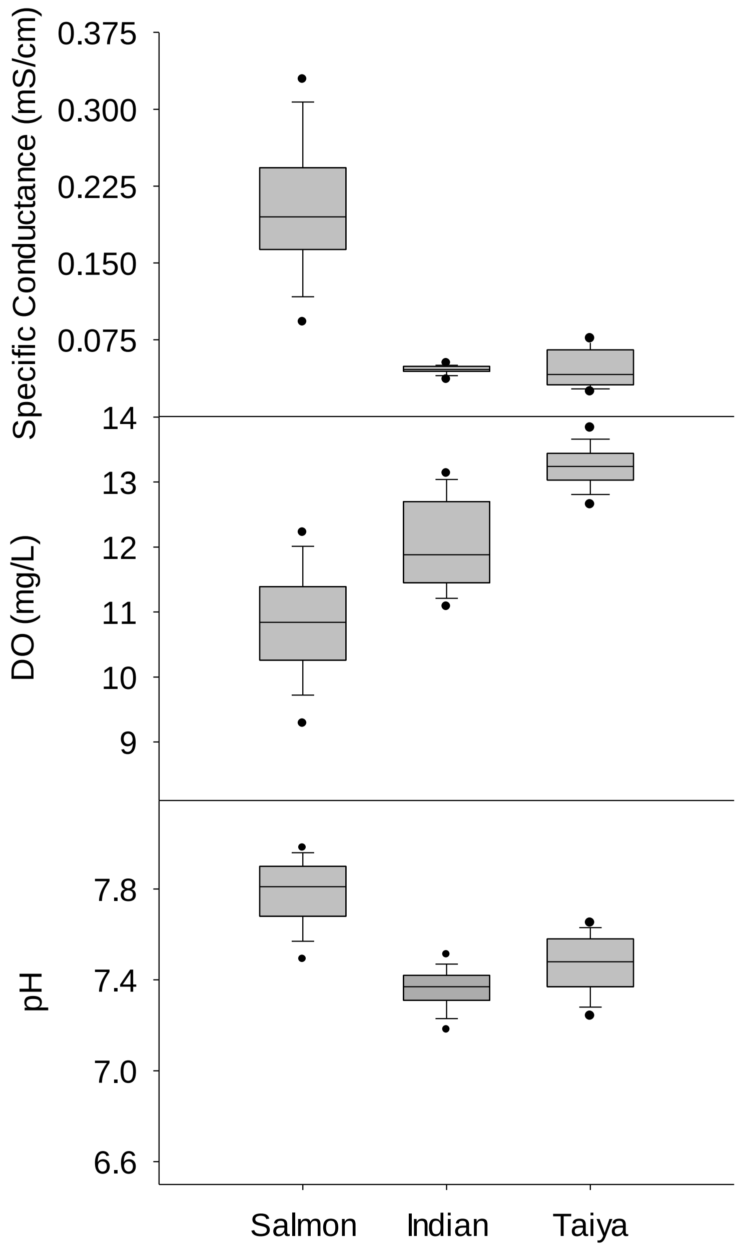


**Figure 3.** Box plots summarizing all valid measurements (data quality rating '0' or '1') for pH, dissolved oxygen (DO), and specific conductance for the Salmon, Taiya, and Indian Rivers in 2017. The horizontal line within each box indicates median values, horizontal lines bounding the upper and lower portion of the boxes represent 25th and 75th percentiles, lower and upper whiskers represent 10th and 90th percentiles, and single points represent 5th and 95th percentiles.

### Taiya River

#### *Temperature*

2017 Taiya River water temperature was generally similar to average daily mean values from 2011-2016 except for short-lived anomalies in late October and early November (Figure 4). During the period of monitoring, the daily mean water temperature in the Taiya River ranged from -0.1 to 6.9°C and peaked on August 18. Historical comparisons of peak temperature days are subjective because in past years the Taiya River's glacially influenced thermal regime has peaked to the same magnitude on multiple days within a given monitoring season. Median daily mean water temperature during the monitoring period was 5.4°C. Monthly mean daily average temperatures ranged from 4.0 to 6.0°C (Table 6).

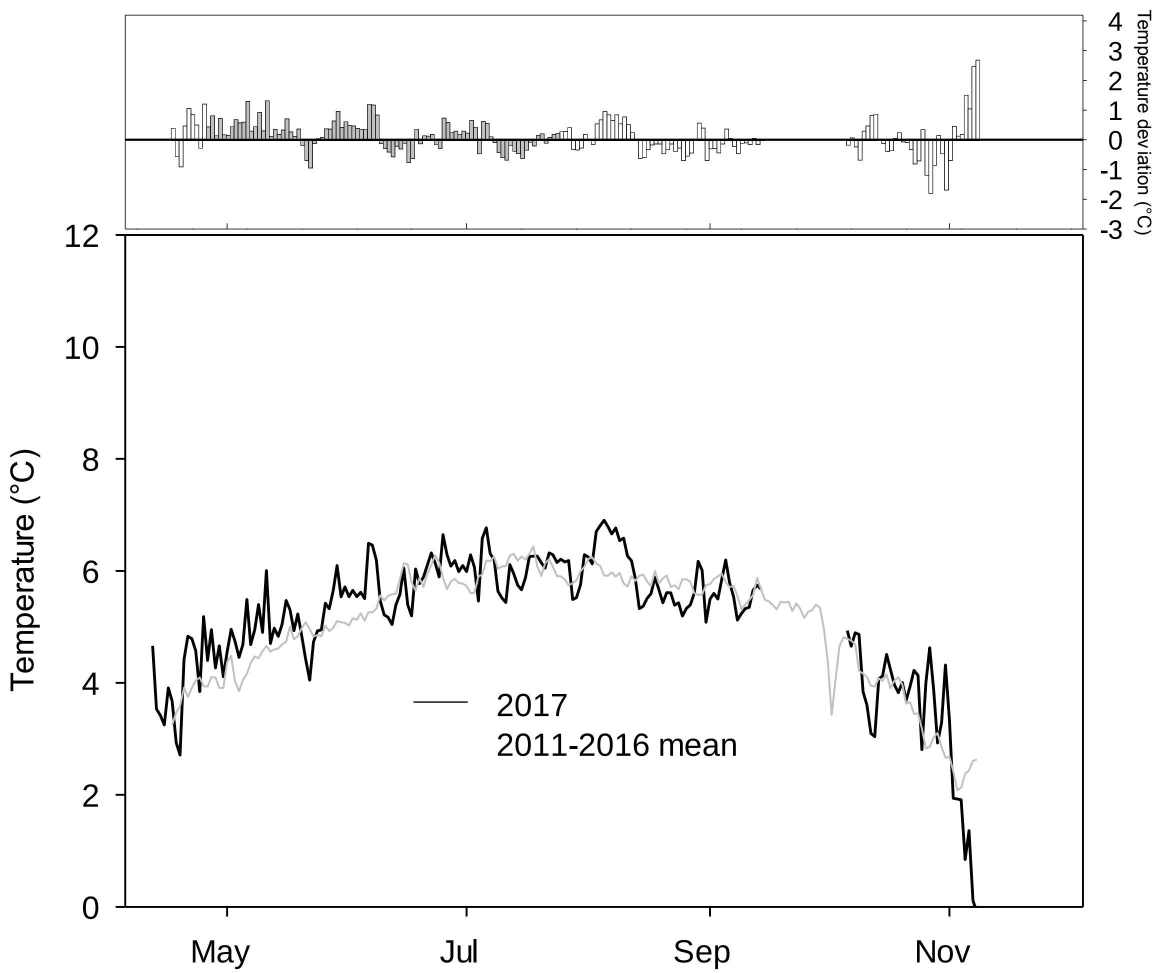


**Figure 4.** Daily mean water temperature for the Taiya River in 2017 and 2011-2016 mean (lower panel) and temperature deviations from 2011-2016 mean (upper thin panel). In the upper panel, deviations were compared against average daily temperatures calculated using 5 years of historical data (white bars) or 6 years (gray bars). Due to the short time series, interpret deviations cautiously.

### ***Turbidity***

In 2017, Taiya River hourly turbidity measurements ranged from 1.0 to 1,045 NTU (slightly higher than the stated turbidity sensor maximum) during the sampling season, with the largest hourly peak event occurring July 30. The daily mean turbidity maximum was 390 NTU and occurred on September 7 (Figure 5). No turbidity data were available from September 14 to October 5. Turbidity events were consistently timed with high flow events most likely caused by increased input of glacial melt water (Figure 11 in Appendix B).

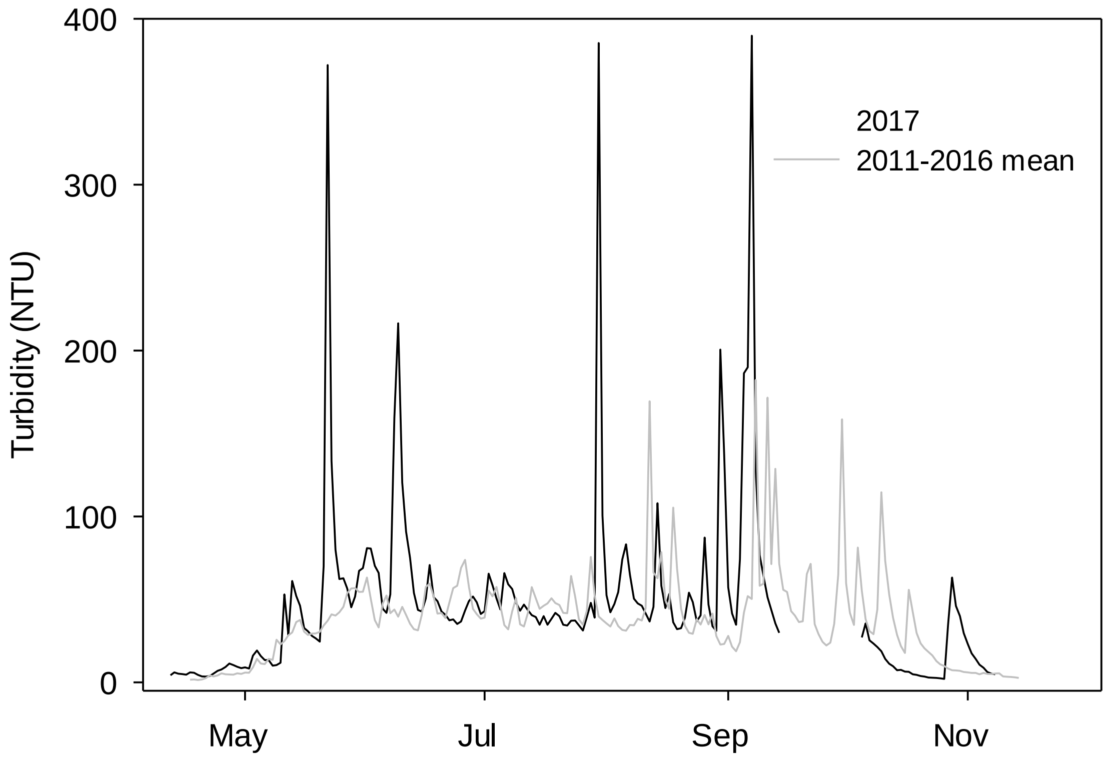


**Figure 5.** Daily mean turbidity for the Taiya River in 2017 and averaged across commonly measured dates in 2011-2016.

### ***Specific conductance, DO, and pH***

In the Taiya River in 2017, individual specific conductance measurements ranged from 0.02 to 0.08 mS/cm with a median of 0.04 mS/cm (Figure 3). DO ranged from 12.2 to 14.4 mg/L with a median of 13.2 mg/L (Figure 3).Values for pH ranged from 7.2 to 7.7 with a median of 7.5 (Figure 3).

## **Indian River**

### ***Temperature***

In comparison to average daily mean values from 2010-2016, 2017 water temperature was consistently warmer than average for the majority of August through September (Figure 6), but this result should be interpreted with caution because of the short time series available. During the period of monitoring, the daily mean water temperature in the Indian River ranged from 4.5 to 10.2°C and peaked on August 14 (2010-2016 average peak temperature date = August 15, standard deviation =

12 days). Median daily mean water temperature during the monitoring period was 7.7°C. Monthly mean daily average temperatures ranged from 6.0 to 9.3°C (Table 6).

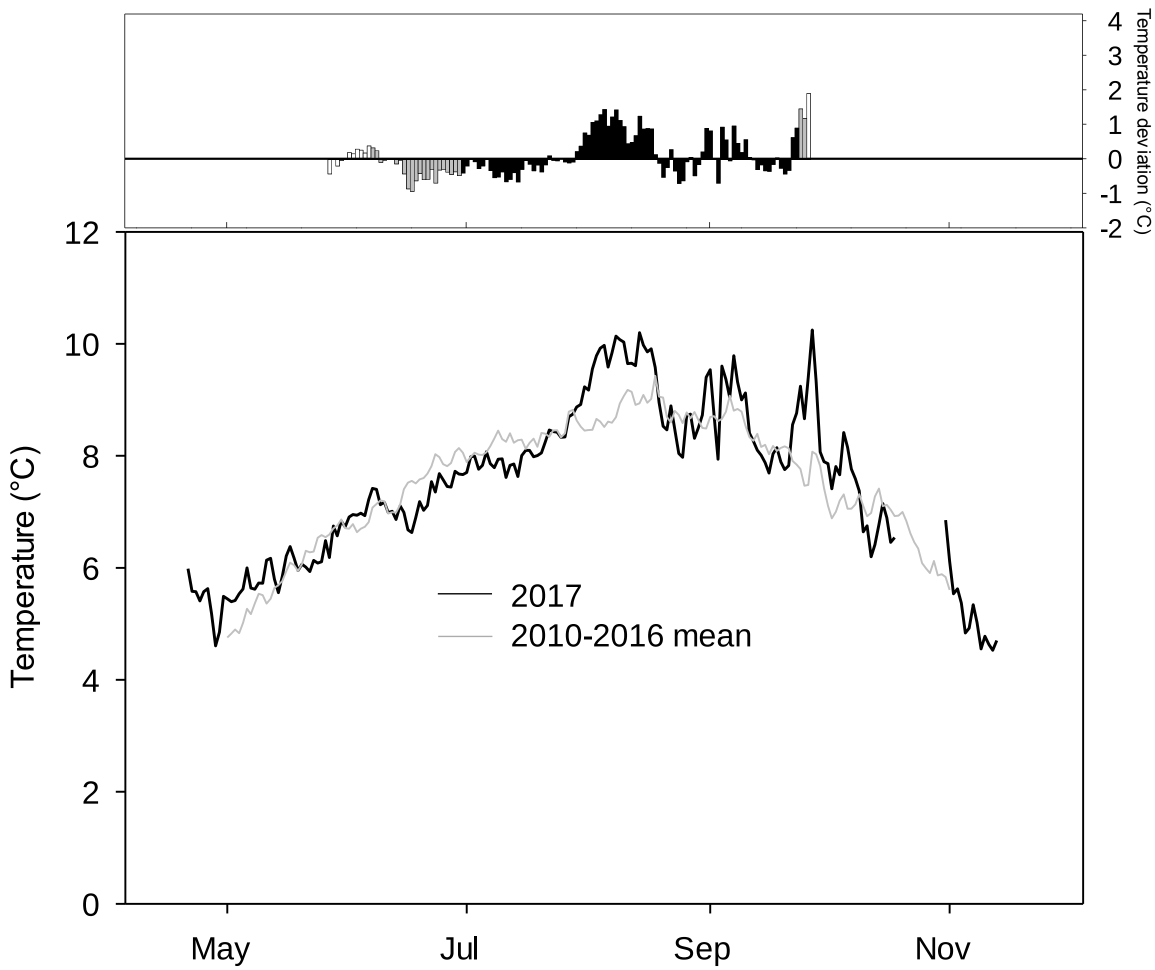


**Figure 6.** Daily mean water temperature for the Indian River in 2017 and 2010-2016 mean (lower panel) and temperature deviations from 2010-2016 mean (upper thin panel). In the upper panel, deviations were compared against average daily temperatures calculated using 5 years of historical data (white bars), 6 years (gray bars), or 7 years (black bars). Due to the short time series, interpret deviations cautiously.

### *Specific conductance, DO, and pH*

In the Indian River, hourly specific conductance measurements ranged from 0.02 to 0.05 mS/cm with a median of 0.05 mS/cm. DO ranged from 10.6 to 13.8 mg/L with a median of 11.9 mg/L (Figure 3). The minimum DO value was reached on August 12. The critically low DO values observed during August 2013 (Sergeant and Johnson 2014; Sergeant et al. 2017) have not been observed again in the years following. Values for pH ranged from 6.7 to 7.6 with a median of 7.4 (Figure 3).

## Compliance with water quality standards

No observations from 2017 indicated exceedances of Alaska Department of Environmental Conservation water quality standards (Tables 7 and 8; ADEC 2017) and water quality values in the three rivers never approached regulatory thresholds. Spikes in turbidity recorded by the Taiya River sonde were timed with high flow events and very likely caused by natural occurrences within the watershed such as glacial run-off.

**Table 7.** Period of record and summary statistics for all freshwater water quality data collected and reported by the SEAN from 2010 through 2017.

| | | | Summary statistics | | | | |
|---|---|---|---|---|---|---|---|
| **River (Period of Record)** | **Parameter** | **# obs.[1]** | **Median** | **Mean** | **Standard deviation** | **Min** | **Max** |
| Salmon (Jun4, 2010 to Nov 1, 2017) | Conductivity (mS/cm) | 35,055 | 0.20 | 0.20 | 0.08 | 0.00 | 0.44 |
| | Dissolved Oxygen (mg/L) | 35,298 | 10.4 | 10.4 | 0.9 | 7.8 | 15.5 |
| | Dissolved Oxygen (% Sat) | 35,298 | 87.7 | 87.5 | 6.6 | 69 | 110.0 |
| | pH | 34,416 | 7.8 | 7.8 | 0.1 | 6.6 | 8.2 |
| | Temperature (°C) | 35,939 | 8 | 7.7 | 2.3 | 0.7 | 13.2 |
| Taiya (Apr 25, 2011 to Nov 9, 2017) | Conductivity (mS/cm) | 32,100 | 0.04 | 0.04 | 0.02 | 0.00 | 0.09 |
| | Dissolved Oxygen (mg/L) | 27,363 | 12.6 | 12.7 | 0.6 | 10.7 | 14.9 |
| | Dissolved Oxygen (% Sat) | 27,363 | 98.8 | 98.8 | 3.7 | 79.8 | 110.5 |
| | pH | 33,102 | 7.4 | 7.4 | 0.2 | 6.5 | 8.8 |
| | Temperature (°C) | 33,333 | 5.2 | 5.0 | 1.6 | -0.1 | 9.6 |
| | Turbidity (NTU)[2] | 32,413 | 28.5 | 38.4 | 58.3 | -2.6 | 1205.9 |
| Indian (May 26, 2010 to Nov 13, 2017) | Conductivity (mS/cm) | 30,575 | 0.05 | 0.04 | 0.01 | 0.01 | 0.08 |
| | Dissolved Oxygen (mg/L) | 29,416 | 11.7 | 11.6 | 1.3 | 1.7 | 14 |
| | Dissolved Oxygen (% Sat) | 29,416 | 99.1 | 97.2 | 9.8 | 15.5 | 108.8 |
| | pH | 27,688 | 7.1 | 7.1 | 0.3 | 5.7 | 8.2 |
| | Temperature (°C) | 31,205 | 7.7 | 7.7 | 1.6 | 2.2 | 12.6 |

[1]Data graded '2' or '3' were not counted as observations; Please see SOP 13 of the Freshwater Water Quality protocol (Sergeant et al. 2013) for descriptions of these water quality ratings.

[2]Slightly negative turbidity values reflect inherent inaccuracy in the 0 NTU calibration procedure.

**Table 8.** Current Alaska Department of Environmental Conservation (ADEC) water quality standards, last amended February 5, 2017 (ADEC 2017). Superscript numbers denote the intended category of water use for which water quality criteria are relevant.

| Parameter | Criteria |
|---|---|
| Specific conductance | None listed by ADEC |
| Dissolved oxygen (DO)[1] | DO must be greater than 7 mg/l in waters used by anadromous or resident fish. In no case may DO be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel used by anadromous or resident fish for spawning. For waters not used by anadromous or resident fish, DO must be greater than or equal to 5 mg/l. In no case may DO be greater than 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection. |
| pH[1,2] | May not be less than 6.5 nor greater than 8.5. May not vary more than 0.5 pH unit from natural conditions. |
| Temperature[1,2] | May not exceed 20°C at any time. The following maximum temperatures may not be exceeded, where applicable:<br>Migration routes 15°C<br>Spawning areas 13°C<br>Rearing areas 15°C<br>Egg & fry incubation 13°C<br>For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms. |
| Turbidity[3] | May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters. |

[1] Growth and propagation of fish, shellfish, other aquatic life, and wildlife

[2] Water supply/aquaculture

[3] Water recreation

# Discussion

## Observed trends

Across all three rivers monitored by the SEAN in 2017, no observed values or trends appeared to signal a fundamental change to existing water quality patterns. The critically low DO conditions of the Indian River observed during the summer of 2013 have not been observed again since that time.

## Program performance

In general, program operations were executed efficiently in 2017, but battery power issues in the Indian and Taiya Rivers led to data gaps of approximately two weeks (Table 3). A future protocol revision will recommend that sonde batteries be replaced in July or August no matter the battery power reading. We have found that once batteries age throughout the season, power drops dramatically over the course of one or two days and logging ceases. We continue to recommend pre-installation training at the start of each season for park staff with less than 3 seasons of water quality monitoring experience. SEAN staff will continue maintaining close communication with park staff to develop feasible staffing solutions each season.

We also continue to see occasional negative turbidity values in some Taiya River field measurements and during monthly error checks (down to -2.6 NTUs). This happens when the sensor is calibrated to 0 NTUs, but the calibrating environment surrounding the sensor (calibration standard and cup) are slightly contaminated. In future years, we will stress the need for the cleanest possible calibration environment and will ensure that optical wiper blades are colored black (white blades can reflect light and change NTU reading; YSI 2010). In some situations, it may be necessary to program a small turbidity offset of 0.2-0.8 NTUs to avoid negative readings. In the next protocol revision, the turbidity error check and calibration routine will be updated to reflect these best practices.

The completion of the 2017 monitoring season marks 8 years of data collection for the Salmon and Indian Rivers, and 7 years for the Taiya River. SEAN staff are currently drafting a water quality synthesis report summarizing multi-year trends, program performance, and future program needs or modifications (see SOP 11 of Sergeant et al. 2013 for more reporting details). The synthesis report is expected to be completed in 2018.

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# Appendix A: Hourly time series by river for all water quality parameters

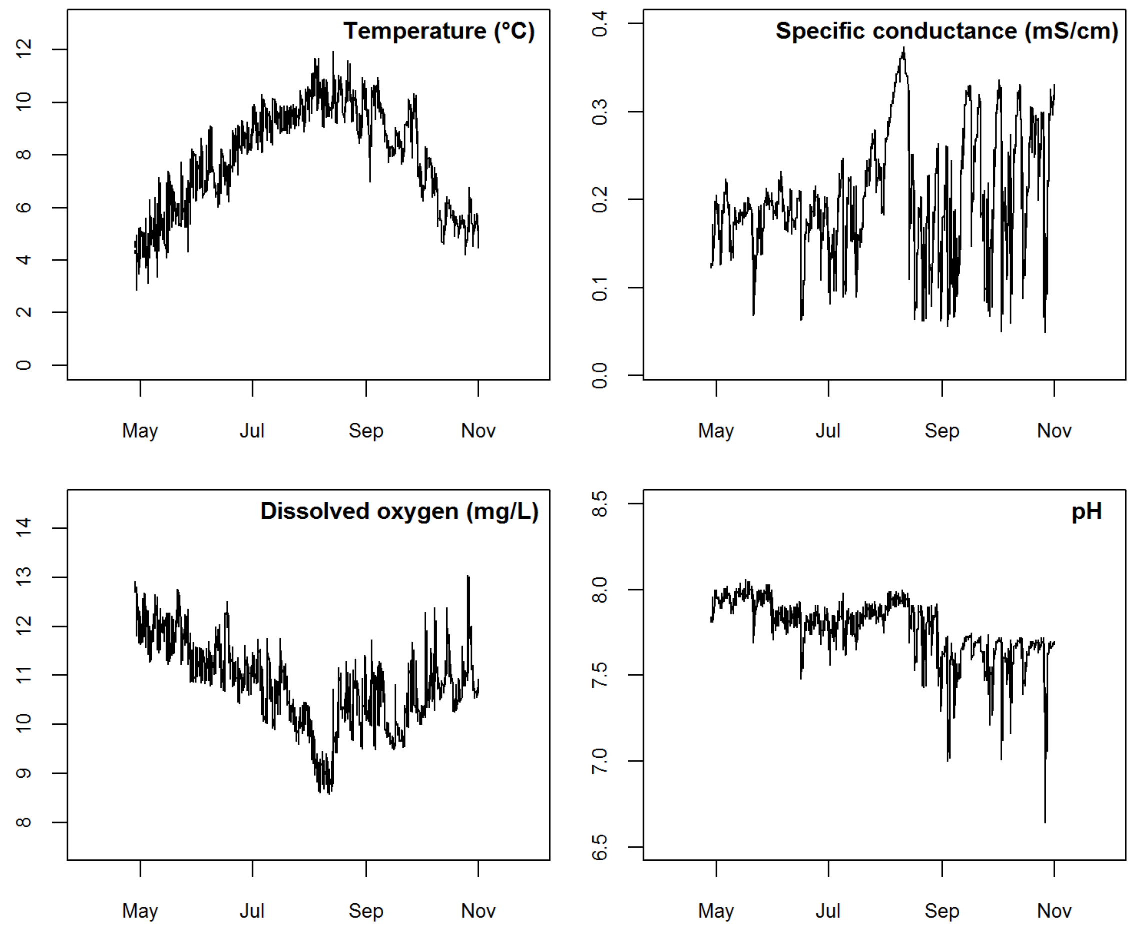


**Figure 7.** Hourly water quality data for the Salmon River in 2017.

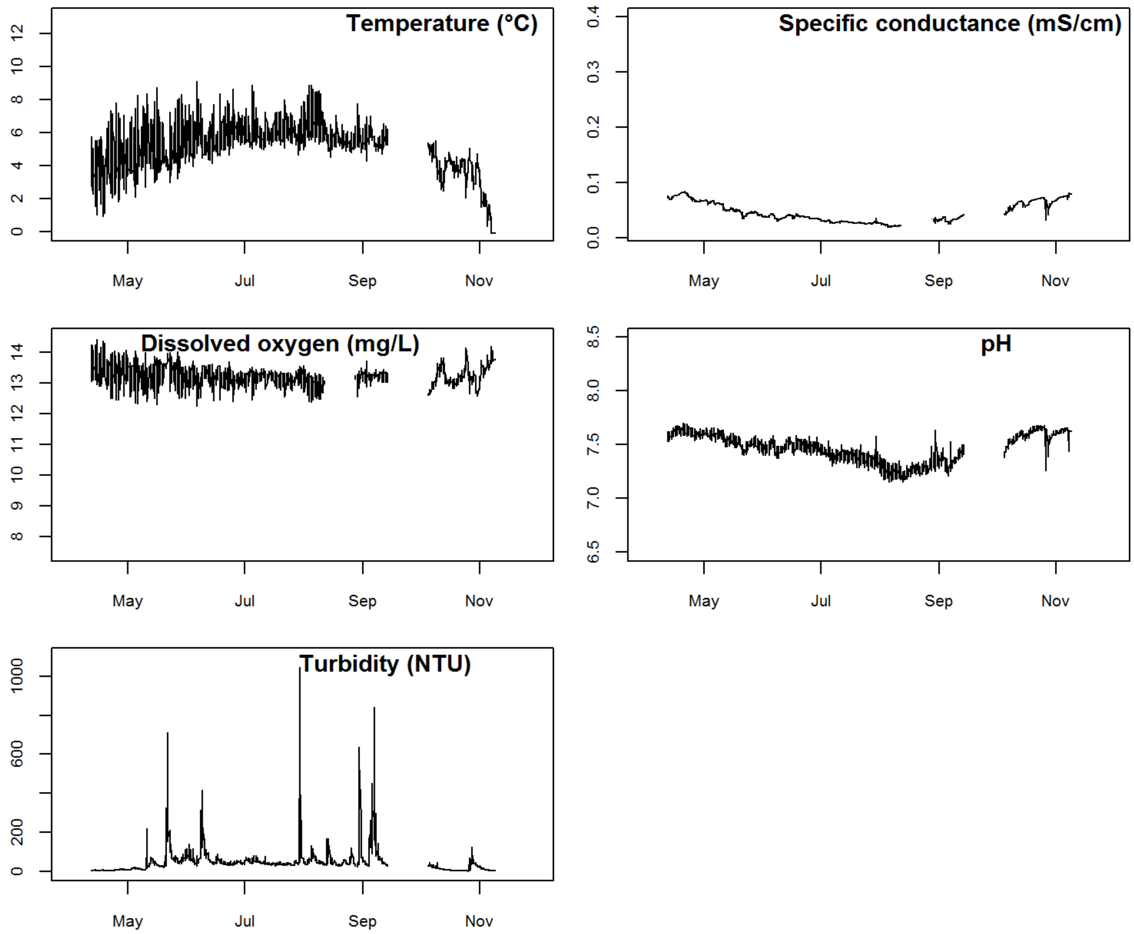


**Figure 8.** Hourly water quality data for the Taiya River in 2017.

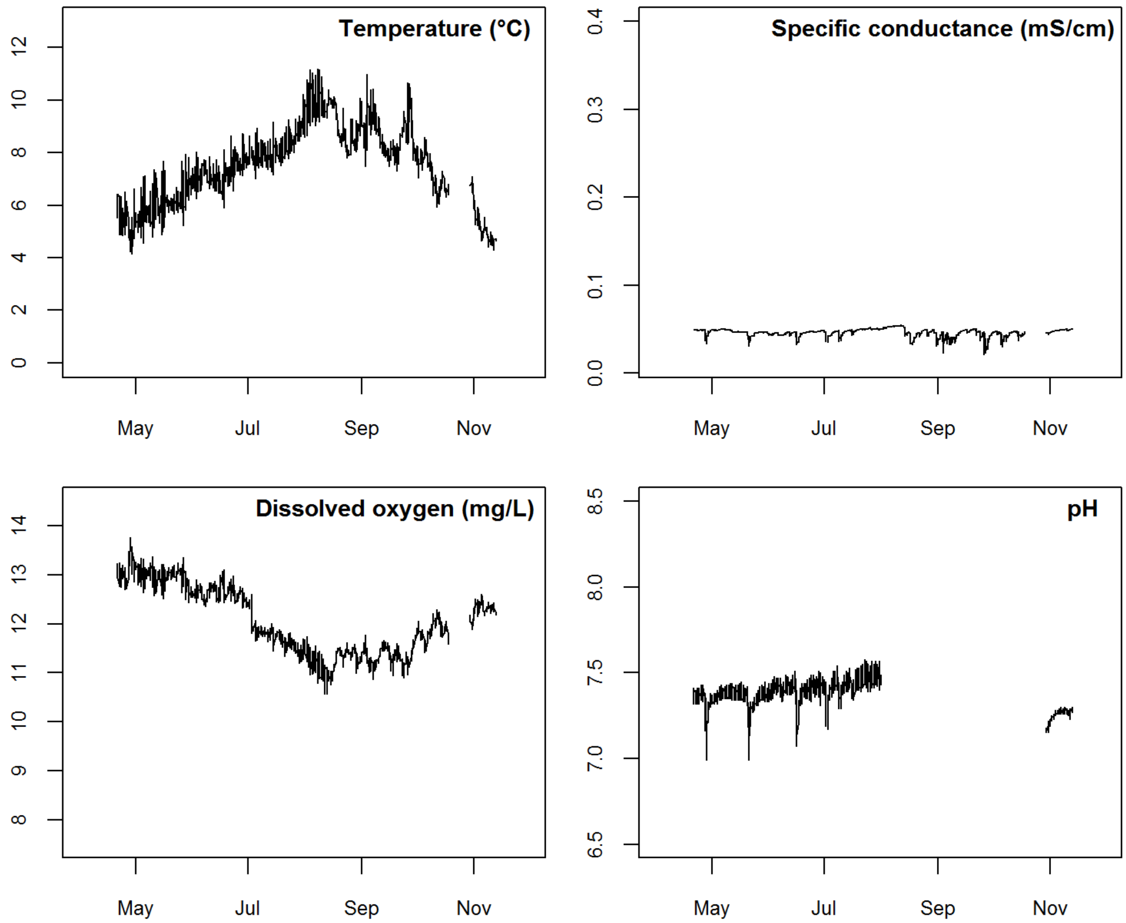


**Figure 9.** Hourly water quality data for the Indian River in 2017.

# Appendix B: Streamflow time series versus all water quality parameters

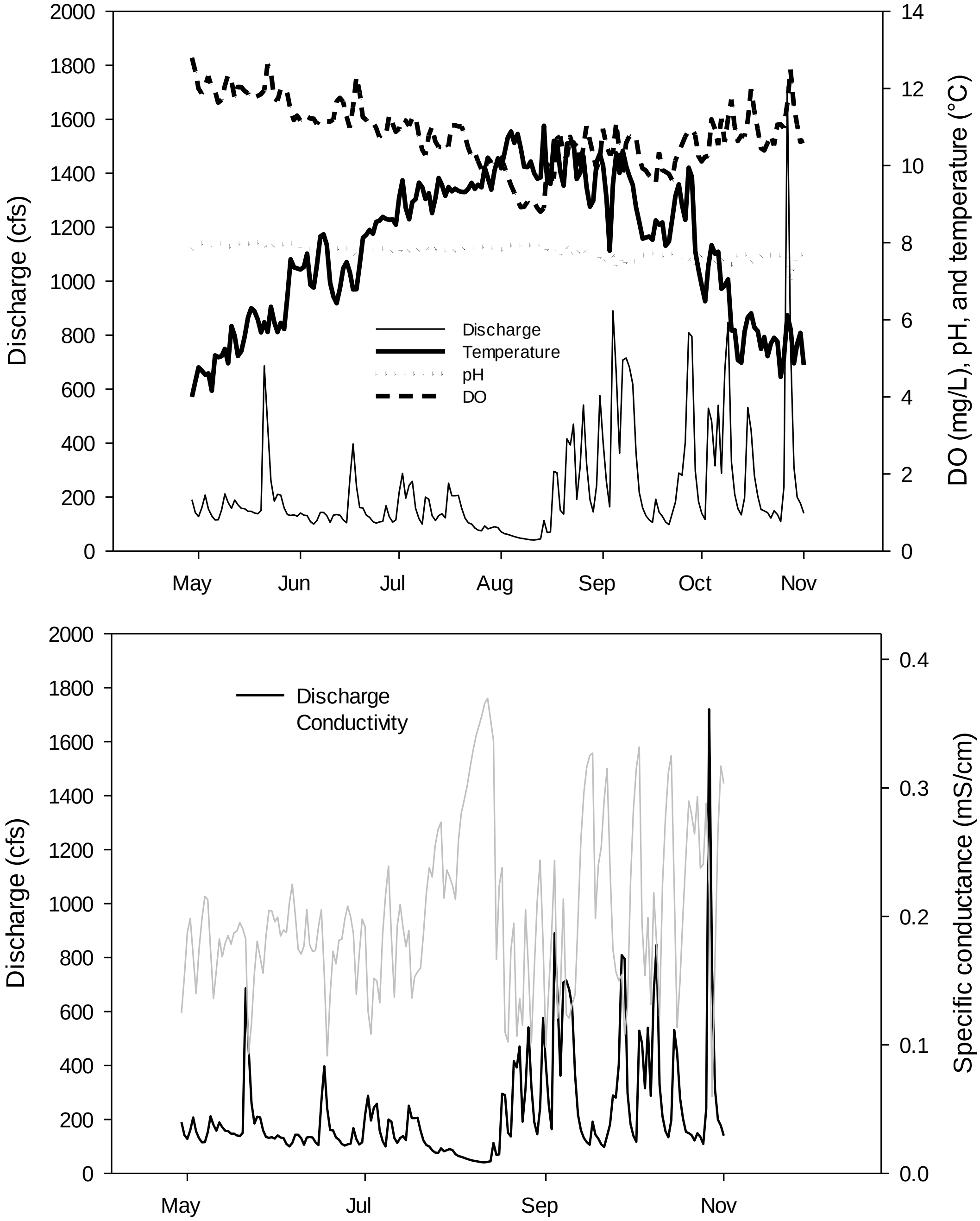


**Figure 10.** Daily average streamflow versus daily averages for all water quality parameters in the Salmon River in 2017. Note the additional Y-axes on each panel. Streamflow data collected approximately 1 km downstream from water quality data and downloaded from the Salmon River USGS gage #1505596 (URL in Table 5). At the time of this report, all data for this time period were marked ‘provisional’ by USGS.

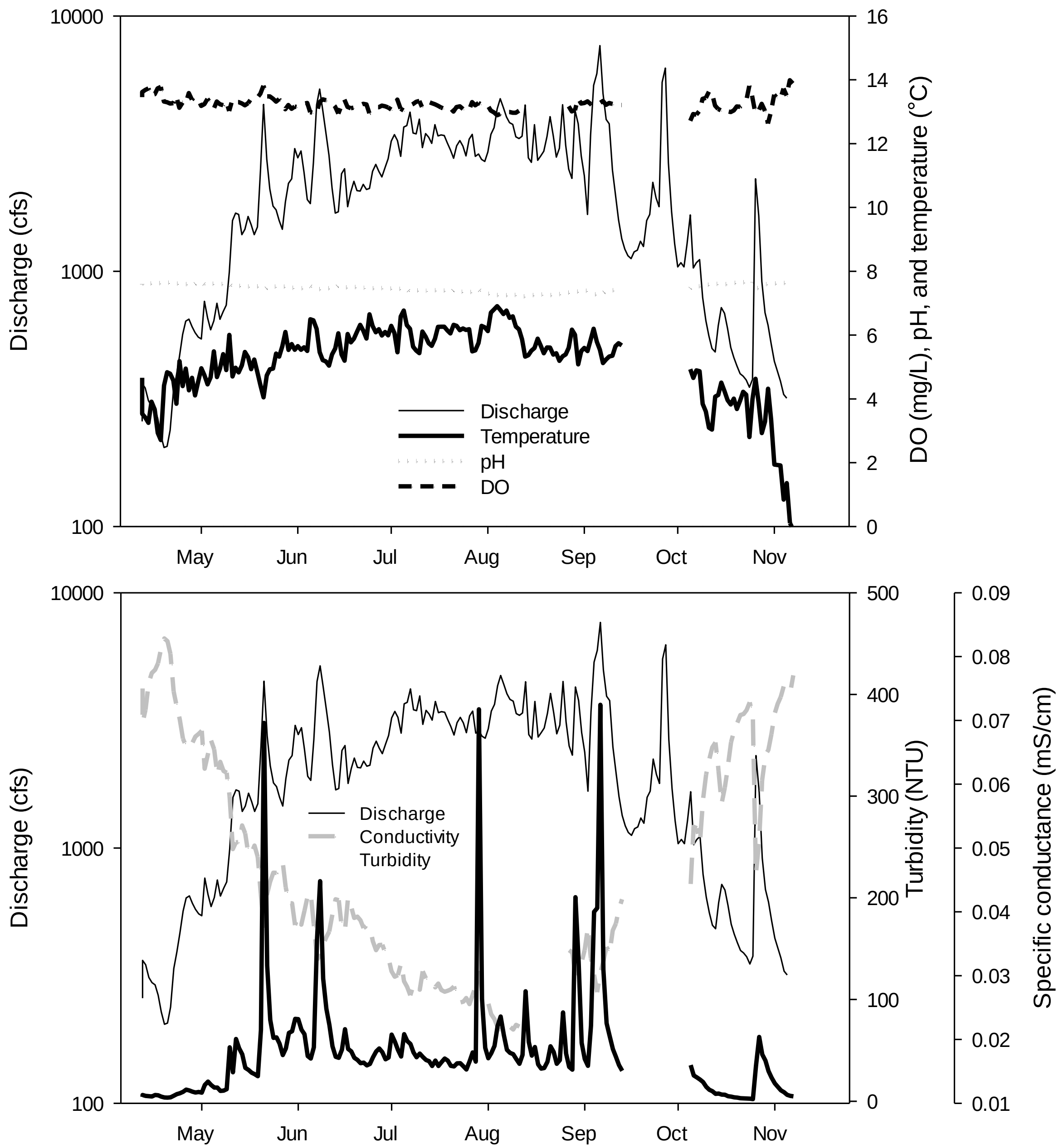


**Figure 11.** Daily average streamflow (log scale) versus daily averages for all water quality parameters in the Taiya River in 2017. Note the additional Y-axes on each panel. Streamflow data collected in the same location as water quality data and downloaded from the Taiya River USGS gage #1505621 (URL in Table 5). At the time of this report, all data for this time period were marked ‘provisional’ by USGS.

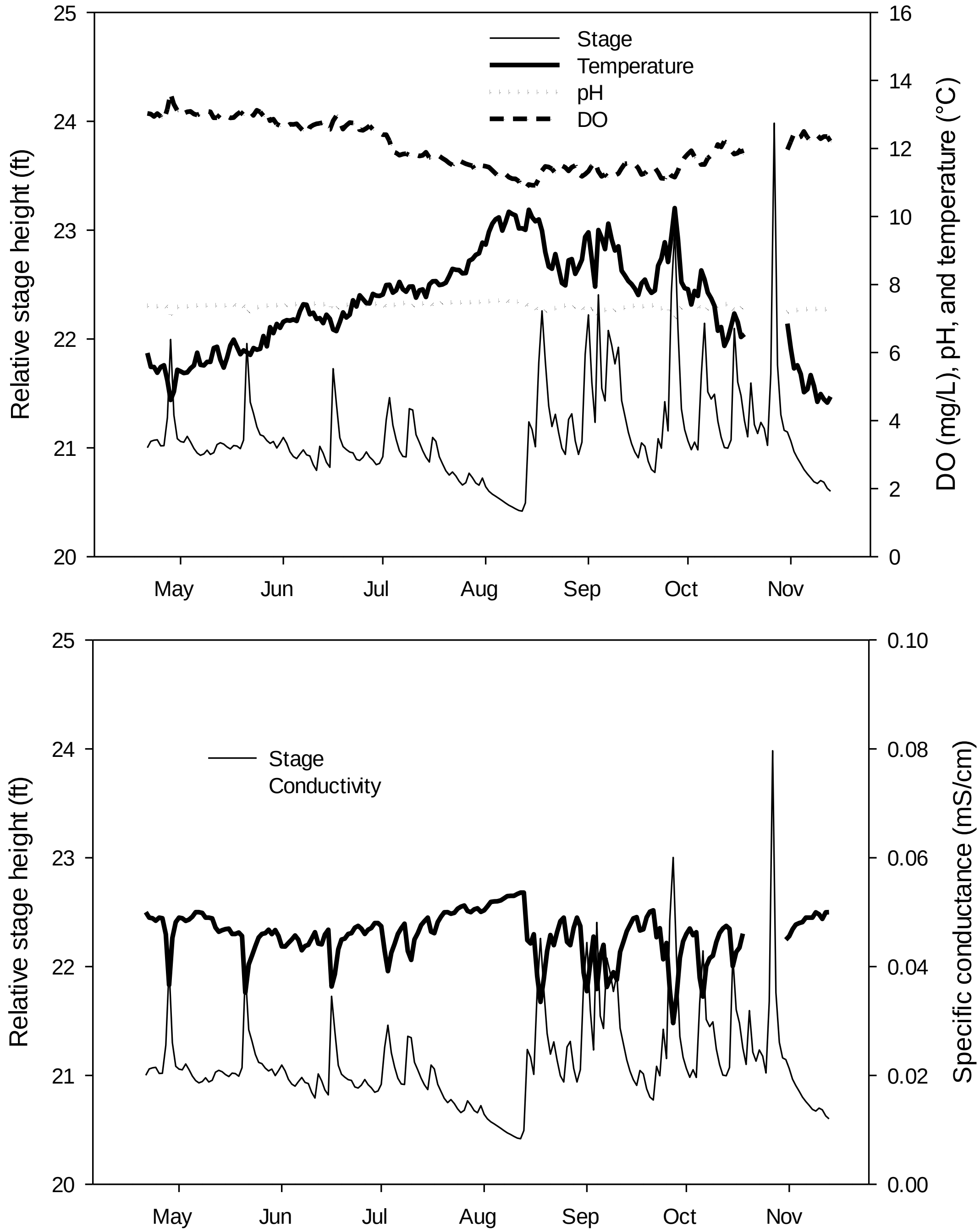


**Figure 12.** Daily average stage height versus daily averages for all water quality parameters in the Indian River in 2017. Note the additional Y-axes on each panel. Streamflow data collected in the same location as water quality data. Stage data collected in the same location as water quality data and downloaded from the Indian River USGS gage #15087700 (URL in Table 5). A rating curve is still under development. At the time of this report, all data for this time period were marked 'provisional' by USGS.

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